Danmarks Meteorologiske Institut

DMI Report 22-12
Harmonie-Climate developments at the DMI in 2021

Final scientific report of the 2021 National Centre for Climate Research Work Package 1.1.1, HCLIM regional modeling

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Contents

1. Scientific summary

Brief description

The regional climate model Harmonie-Climate (HCLIM) is under development as an offspring from the weather prediction model Harmonie. This development is performed in an international consortium currently led by SMHI, which the DMI has recently joined. The model is being introduced at the DMI as the next-generation regional climate model to replace the obsolescent HIRHAM5 model. In contrast to the older model, Harmonie-Climate is a non-hydrostatic convection-permitting model, which as a consequence can be run in much higher resolutions than it was possible with HIRHAM5.

The plan has been to adapt the model to the DMI high-performance computer (HPC) and to perform high-resolution experiments on either the DMI or the ECMWF HPC facility.

Results

The model has been compiled successfully on the DMI super computer. Work is still ongoing in order to optimize boundary file preparation and performance in general.

At the ECMWF HPC, simulations with HCLIM have been performed in an unprecedentedly high resolution of 750 m for Denmark for 35 model months.

An already existing set of simulations in 3 km covering all of Scandinavia has been further analysed in collaboration with the Scandinavian part of the HCLIM consortium, the Swedish, Norwegian, and Finnish meteorological institutes.

Status and Perspectives

The work on developing HCLIM will continue in 2022 supported with funding from NCKF-2022.

The output of the 750-metre simulation is currently being analysed. This simulation will be documented and analysed in a manuscript to be submitted to a suitable scientific journal in 2022. Preliminary results indicate that the 750-metre version simulates geographical distribution of precipitation much more realistically than the 5-km version.

The 3-km simulation, done before NCKF-2021, has already been documented in several papers, and more are coming with further analyses of specific aspects.

2. Scientific report

In the following we shall show some results from the 750 m simulation and compare with a coarser-resolution simulation at 5 km grid point distance, which was used as the driving model for the high-resolution simulations.

The concrete simulation procedure started with a selection of 5 years in the recent past, where Denmark at some point has experienced extremely heavy summer precipitation. The selected years were 2007, 2011, 2014, 2015, and 2017. For each year a simulation of the 7 months April-October has been performed.

In order to reach this very high resolution, starting from the recent state-of-the art reanalysis ERA5 (Hersbach et al., 2020) under development at the ECMWF, we have employed a double nesting: The global ERA5 fields in around 31 km resolution has been driving a 5-km HCLIM simulation (DKC05) covering Denmark as well as relevant parts of the North and Baltic Seas, and of northern Germany and southern Scandinavia. This simulation in turn has been driving the 750-metre simulation DKC750, which covers Denmark including Bornholm. The extent of the integration domains can be seen in Fig. 1.

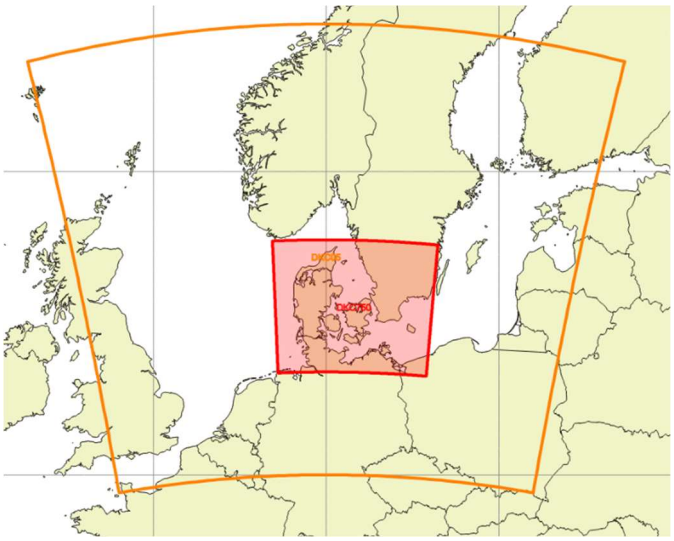

Figure 1 The two HCLIM domains. DKC05 (5km grid distance) and DKC750 (750m grid distance).

The analysis of the DKC750 simulation is still ongoing. A very illustrative interim result can be seen in Fig. 2. At the time of plotting, only 22 of the planned 35 months had been completed. These months come from the four years 2007, 2011, 2014, and 2017, which all started in April, but had not all completed at the time. We therefore show average precipitation for the exact 22 months, which the DKC750 simulation had completed, for an observation based data set (top left; Klimagrid Danmark, Scharling and Wang (2010)), for DKC05 (top right) and for DKC750 (bottom right). For comparison, we show the average present-day summer precipitation for the more than 100 EURO-CORDEX simulations (Jacob et al., 2014; www.euro-cordex.net), which have been run in

around 12 km resolution over Europe in transient simulations 1951-2100 following various RCP emission scenarios (bottom left).

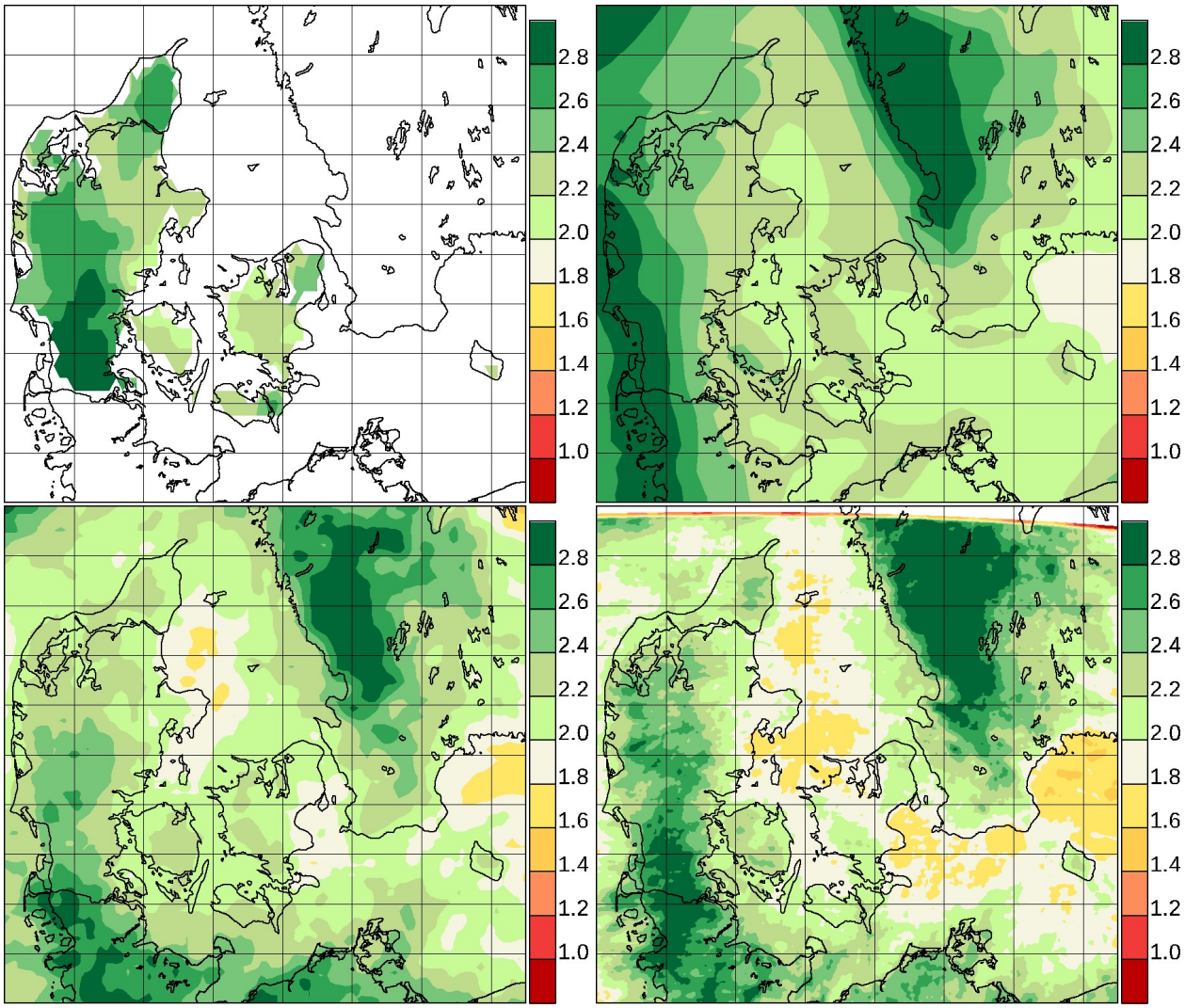

Figure 2 Top left: Average precipitation for 22 of the 35 months of the simulation according to the Klimagrid-Danmark gridded gauge-observation based dataset. Bottom left: Summer climatology from the EURO-CORDEX ensemble. Top right: Average precipitation for 22 of the 35 months of the simulation according to the DKC05 simulation. Bottom right: Same quantity from the DKC750 simulation.

It is immediately obvious that the EURO-CORDEX simulations have a completely unrealistic geographical pattern of summer precipitation, as it falls on the western coast of Jutland and not in the middle. It should be noted that EURO-CORDEX is state-of-the-art for non-convection-permitting simulations, and that patterns at larger geographical scales are quite realistic. The size of Denmark is simply too small for the intended level of detail of this kind of simulations.

The two HCLIM simulations are visibly much closer to the observations. And DKC750 is also obviously closer to the gauge-based observation set than the coarser DKC05 simulation.

This is a very good sign. However, we expect even better added value of the increased resolution when looking at precipitation extremes. Currently, this analysis is ongoing, both wrt. daily and

hourly extremes from the 35 simulated months. As a preliminary result we show in Fig. 3 the 1-year return value of hourly precipitation in the months analysed. In other words, we have sorted all hourly precipitation values in each point, and we plot the 5th largest, as there are 5 years.

There is surprisingly little difference between the two resolutions and even a tendency for the coarser-resolution DKC05 simulation to have higher values. Further analyses will take place to verify the results and to find reasons behind these results. At the moment we have not validated the result.

In conclusion, these simulations for Denmark, which have been performed with unprecedentedly high resolution for a period of this length, show promising results, but the analyses have just started.

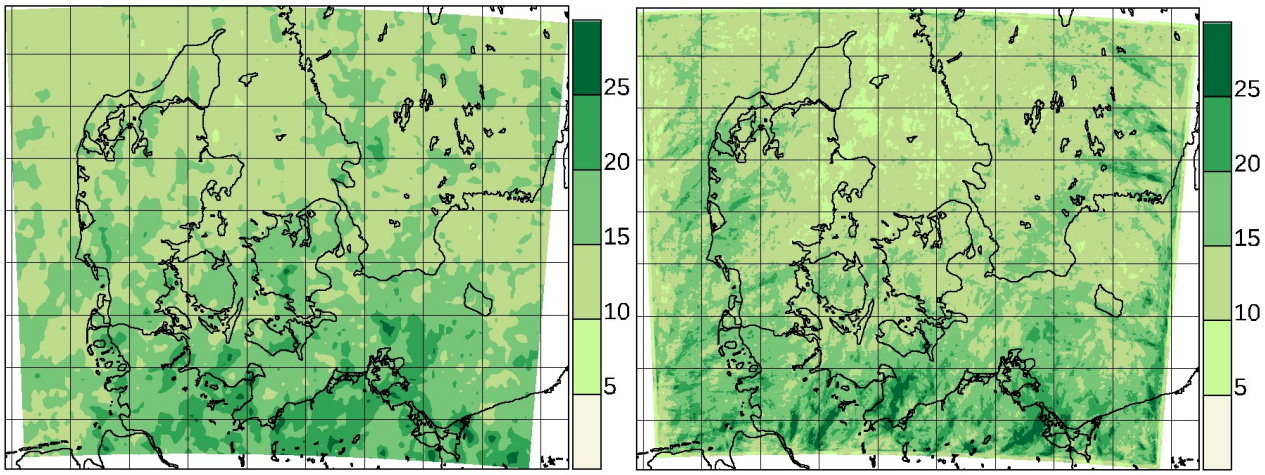

Figure 3 One-year return values of hourly precipitation (mm) for the period April-October based on simulations for 2007, 2011, 2014, 2015, and 2017. Left panel: DKC05; right panel: DKC750.

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